Design for the Environment: Where's the Green and Gold?

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Agenda

- Introduction to the value of DfE
- Review DfE Tools
- Examples

Importance of Scale
“Flying at 30,000 feet”

And at 4 feet

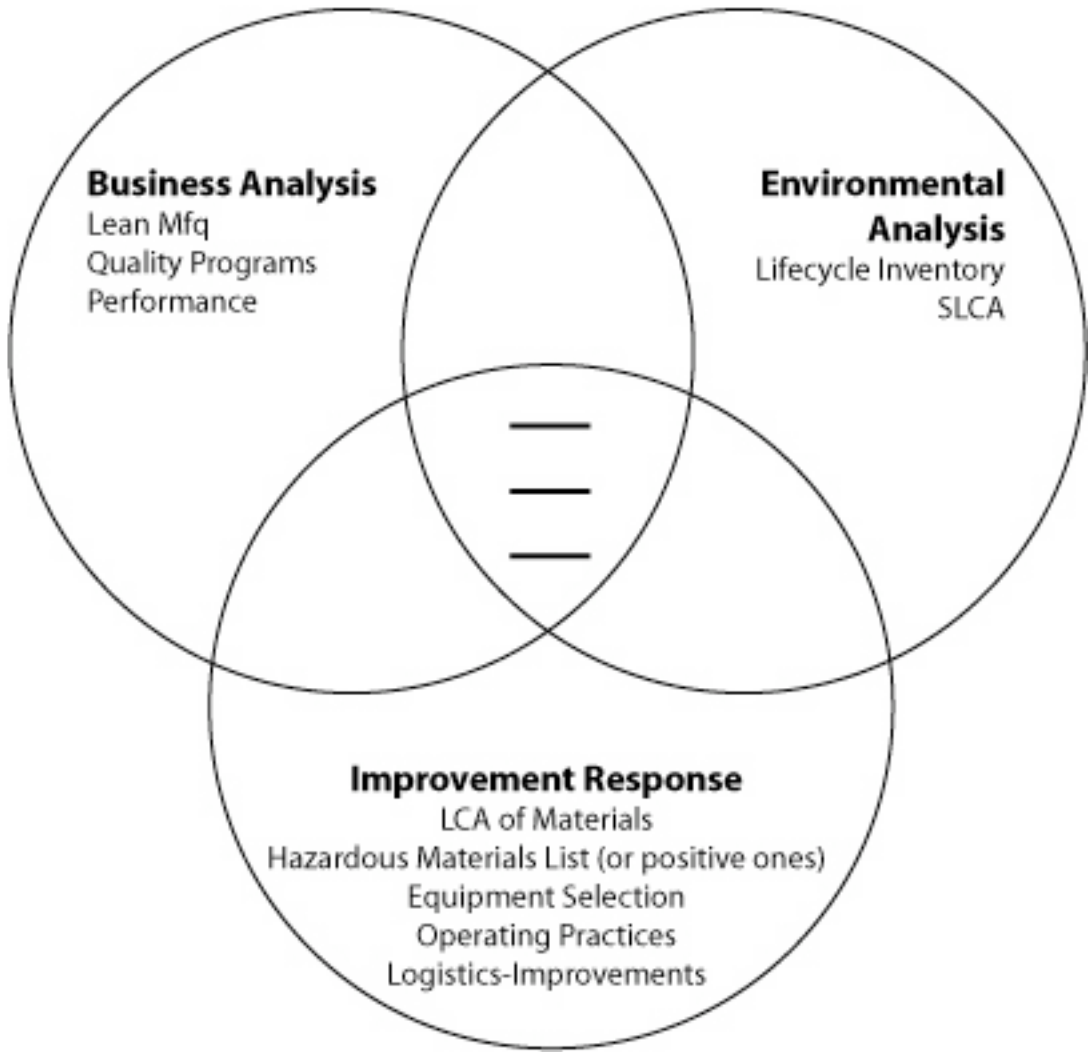

6' of scrap lumber: $ 1.27
8 screws: $ 0.72
BURGER KING
Aerodynamic advantage: Priceless

Perspective

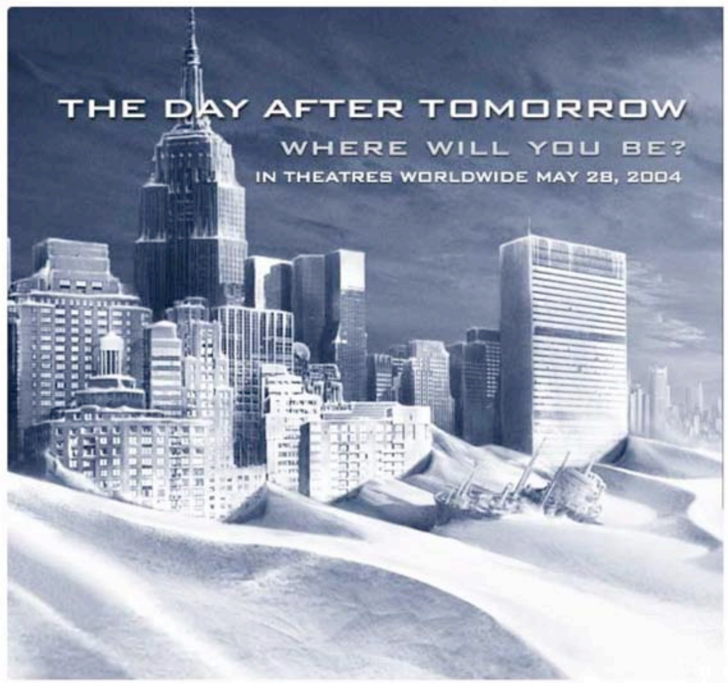
- Most people/professionals are interested in improving their welfare in an environmentally conscious way
- Most people/professionals don't know how to do that
- Environmental design is a leveraged way to move towards environmental performance

Perspective

- There are three dimensions to improving environmental performance.
  - Business Decisions
  - Environmental analysis
  - Environmental improvement
- This talk is based on insight and generalization from ten years of design tool development and application--inductive talk not deductive


Business Analysis
Lean Mfq
Quality Programs
Performance
Environmental Analysis
Lifecycle Inventory
SLCA
Improvement Response
LCA of Materials
Hazardous Materials List (or positive ones)
Equipment Selection
Operating Practices
Logistics-Improvements

What is the state of the Environment?



Connect the Dots

Relating Current Problems to Industrial Responses to Yesterday's Need

Yesterday's Need	Yesterdays Solution	Today's problem
Nontoxic, non-flammable Refrigerants	Chlorofluoro-carbons	Ozone Hole
Automobile engine knock	Tetraethyl lead	lead in air and soil
Locusts, malaria	DDT	adverse effects on birds and mammals
Fertilizer and aid to food production	Nitrogen and Phosphorus fertilizer	Lake and estuary eutrophication

Current Status

- Accumulating scientific evidence of global change and environmental effects
- Persistent bio-accumulators and other environmental problems--Mercury
- Political debate often pits reserved plausibility against unrestrained hyperbole.
- Anti science opposition argue that science is flawed and driven by ideology

Eco Products 2001

Current Status

Table 9: Status of Materials Used in Electronic Applications in Key Global Markets

	Americas	Europe	Asia
Pb	2007	2006	2006
Cd	2007	2006	2006
Hg	2007	2006	2006
Cr (VI)	2007	2006	2006
PBBs	2007	2006	2006
Penta BDEs	2007	2006	2006
Octa BDEs	2007	2006	2006
Deca BDEs	2007	2006	2006
TBBPA			

Color Code:
Green = no restrictions on the horizon
Yellow = voluntary restriction or requirement not likely to be in effect within 5 years (but probably will later)
Red = is or likely to be restricted within 5 years (2009)

Environmental Impact Equation

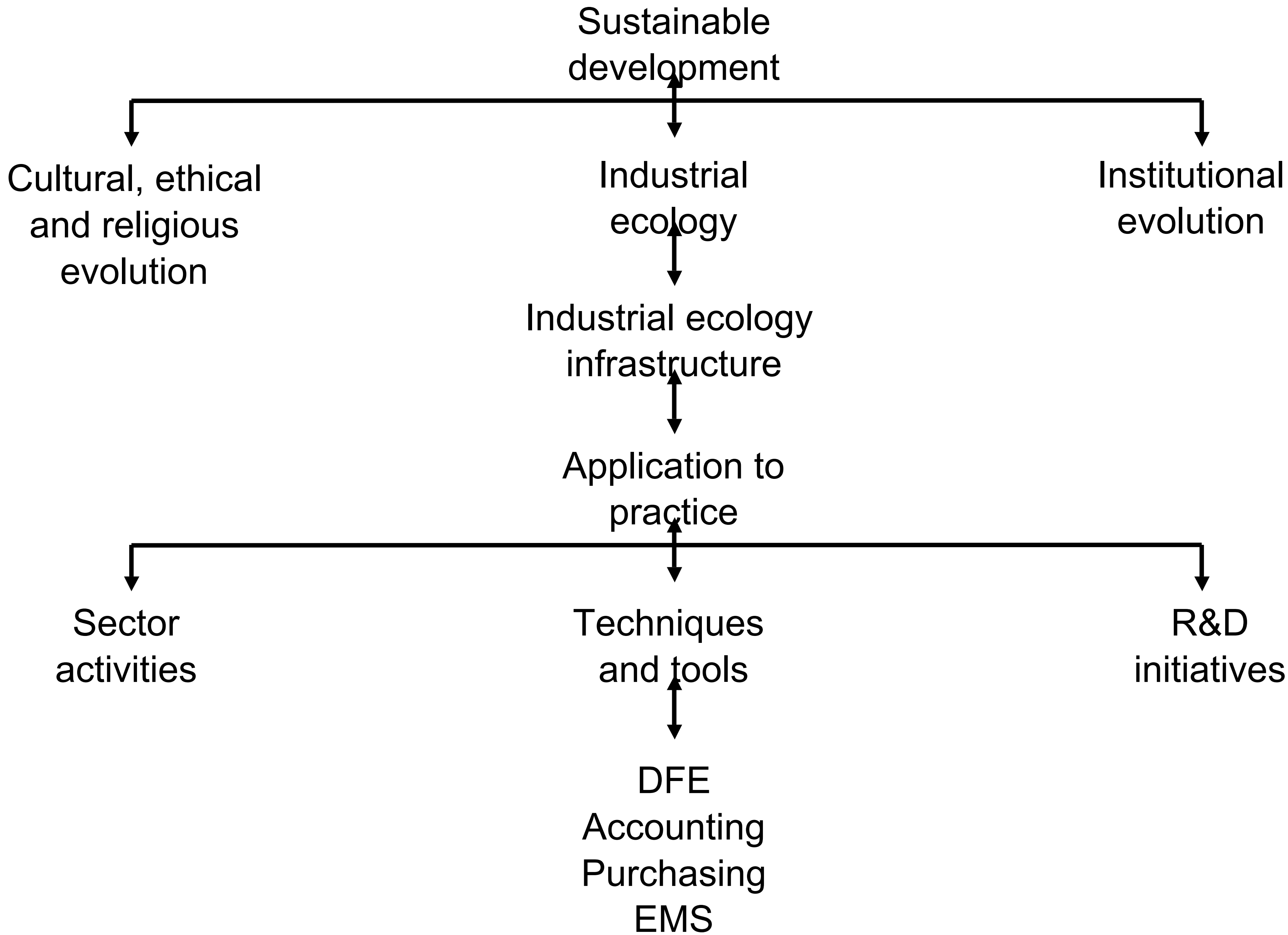
- Environmental Impact = Population x wealth/unit population x environmental impact/unit wealth
  - term 1: growing
  - term 2: growing rapidly
  - term 3: technology term to com-pensate for terms 1 and 2

A brief introduction to Industrial Ecology

Definition

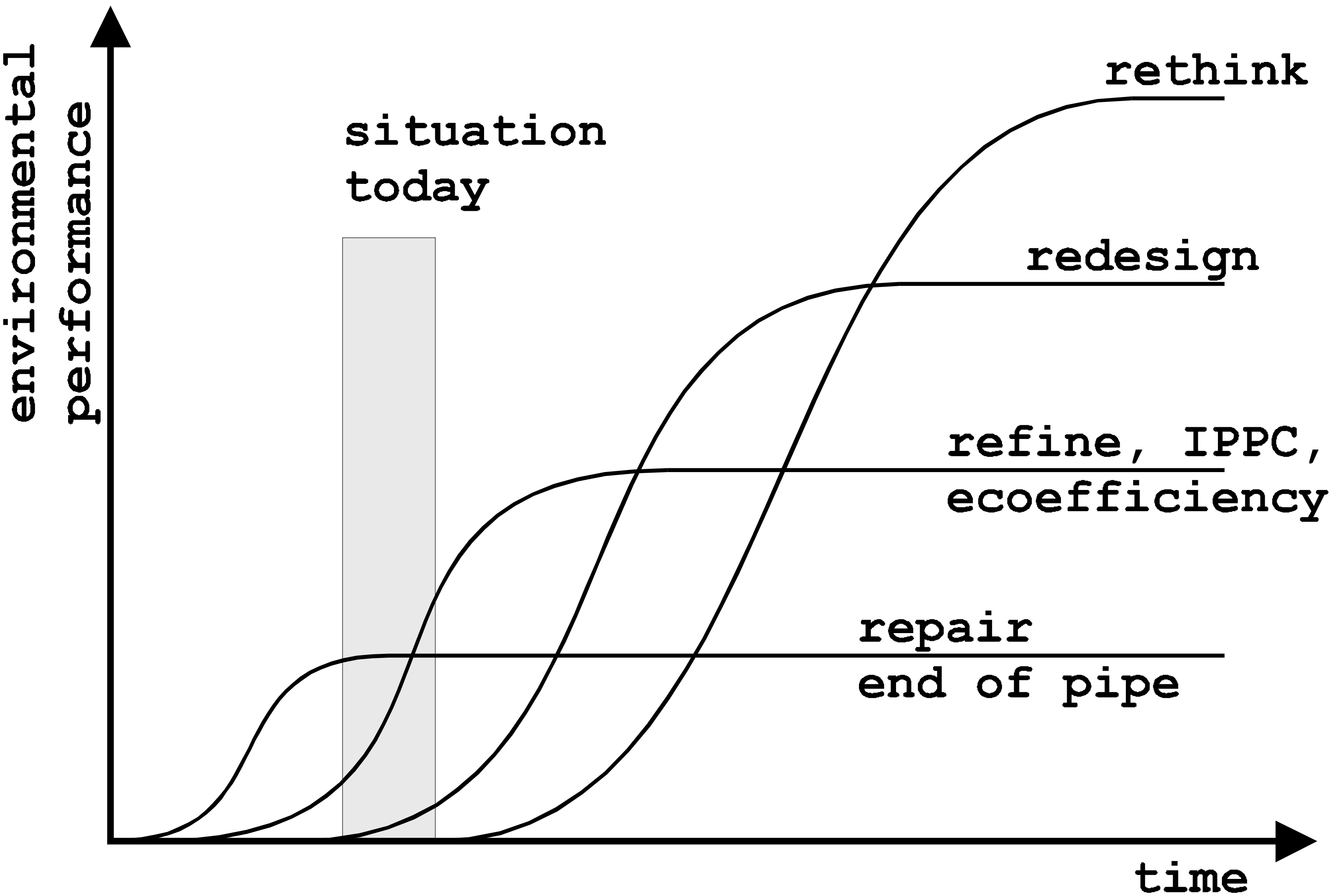
- "Industrial ecology is the means by which humanity can deliberately and rationally approach and maintain a desirable carrying capacity, given continued economic, cultural, and technological evolution. The concept requires that an industrial system be viewed not in isolation from its surrounding systems, but in concert with them." (Graedel and Allenby, 1994)

Industrial Ecology Intellectual Framework



Some typical activities include:

- Designing industrial ecosystems
- Product life extension
- Design for the environment
- Industrial metabolism
  - Energy
  - Material flow


environmental
performance
situation
today
rethink
redesign
refine, IPPC,
ecoefficiency
repair
end of pipe
time

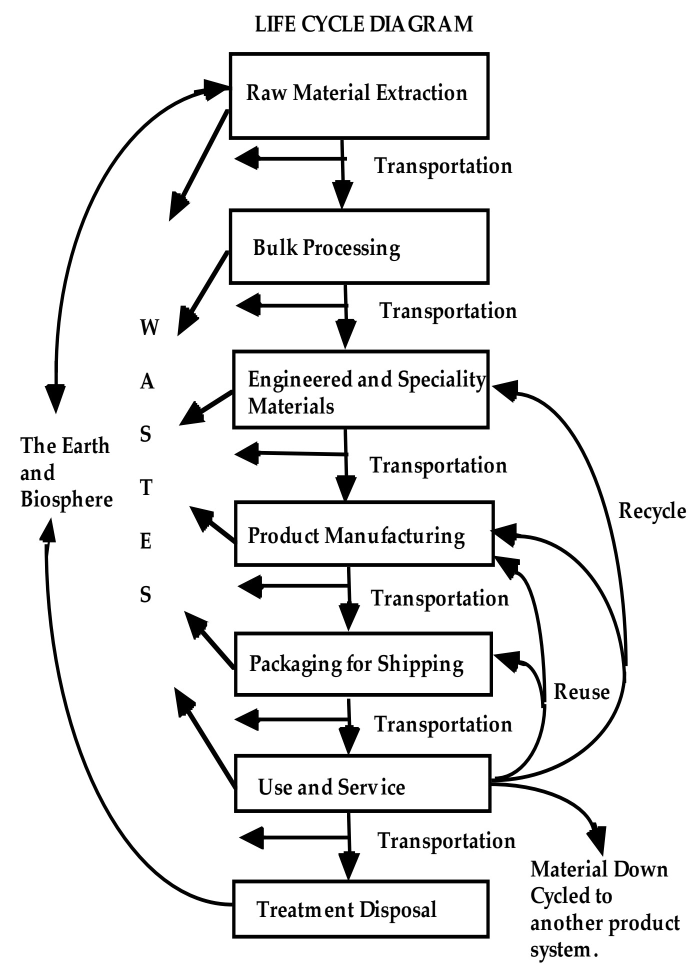
What does this mean from a product design standpoint?

- You will design product life cycles not products.
- You will select materials using different criteria
  - Availability
  - Renewability
- You will be concerned about the fate of the product after its useful life.

You will be interested in:

- DF(x) Durability, Remanufacturing, etc
- Eco-efficiency
- Energy consumption
- Closed loop manufacturing
- Product only plants

Now let's look at Some Specifics


LIFE CYCLE DIAGRAM
Raw Material Extraction
Transportation
Bulk Processing
Transportation
Engineered and Speciality Materials
Transportation
Product Manufacturing
Transportation
Packaging for Shipping
Transportation
Use and Service
Transportation
Treatment Disposal
The Earth and Biosphere
W A S T E S
Recycle
Reuse
Material Down Cycled to another product system.

Soap Example

Checklist Joining Techniques

Fields of Action (Joinings)	Result ● Please mark correspondingly with a cross →	Need for Action ☺	 😐	 ☹
Location	● visible	⊗		
	● covered		⊗	
	● hidden			⊗
Disconnectability	● can be disconnected nondestructively	⊗		
	● can be disconnected destructively		⊗	
	● can only be disconnected by the destruction of parts			⊗
Accessibility	● accessible in axial dismantling direction	⊗		
	● axial accessible		⊗	
	● radial or difficult accessibility			⊗
Number of Joinings	● one/few joining elements	⊗		
	● low (depending on function)		⊗	
	● high			⊗
Variety of Joinings/Tools	● standardized joining elements	⊗		
	● standardized within the kinds of joinings		⊗	
	● not or almost not standardized			⊗
Need for Tools	● disconnection wihout tool	⊗		
	● universal tools		⊗	
	● special tools			⊗
Mechanization Automatization of the Dismantling/ Disassembling	● can be automated	⊗		
	● can be mechanized		⊗	
	● manual work necessary			⊗
Conclusion:		ideal	acceptable	urgent need for action

Figure 26: Checklist for the design of joining techniques regarding recycling / upcycling

18.1.2 Chlorine (Cl_2)

The APME reports (APME 1994a) are the basis for the present data. As with plastics, they were modified and supplemented using the procedure described in Chapter 11.1.

Energy consumption: 1000 kg Chlorine

Final energy source	Energy supply [MJ]	Final process energy Amount		[MJ]	Transport Amount		[MJ]	Total [MJ]
Electricity	11'290	1'389	kWh	5'000	6	kWh	20	16'310
Hard coal	140	32	kg	970		kg		1'110
Crude oil products	120	15	kg	650	7	kg	290	1'060
Natural gas	130	70	m3	2'810	0	m3	10	2'950
Others				40				40
Total	11'680			9'470			320	21'470
							Feedstock [MJ]	
							Sum total [MJ]	21'470

Table 18.2: Energy consumption for the production of 1000 kg chlorine

Life cycle inventory: 1000 kWh Chlorine

Resources, commercial fuels		
Raw brown coal	kg	200.
Crude gas (natural gas)	m3	100.
Raw hard coal	kg	260.
Crude oil from drilling well	kg	78.
Uranium from ore	g	14.
Potential energy water	MJ	720.

Resources, feedstock		
Iron ore	kg	0.65
Limestone	kg	18.6
Rock salt	kg	1'210.
Sand, clay	kg	0.2
Process and cooling water	m3	0.9

Main product		
Chlorine (pure)	kg	1'000.

Co-products
are considered via allocations

Waste treatment		
Wastes in WIP	kg	0.3
Wastes in reactor landfill	kg	27.
Refuse at degradation site	kg	72.

Table 18.3: Life cycle inventory for 1000 kg chlorine

Life cycle inventories: Overview of plastics (conclusion)

Main product: (1000 kg)		HIPS moulding compound	Expandable PS (granules)	PVC powder	PVDC granules	PET granules (amorphous)	PET (partially crystalline)
Air pollutants							
Dust/particulates	g	2'000.	2'000.	3'900.	10'000.	3'500.	3'800.
Benzene (C_6H_6)	g	5.9	4.2	2	4.1	3.4	3.7
PAH policycl. arom. HC	g	3.	<1	0.02	0.041	0.015	0.017
Aromatic HC	g	200.	220.	7.3	15.	8.2	9.
Halon H1301	g	0.13	0.09	0.037	0.073	0.07	0.076
Halogenated HC	g	0.00013	0.000098	0.00036	0.00079	0.00021	0.00024
Methane (CH_4)	g	11'000.	11'000.	5'700.	10'000.	3'700.	3'700.
NMVOC non-methane HC	g	3'800.	4'700.	14'300.	23'000.	35'300.	36'300.
Carbon dioxide fossil (CO_2)*	g	2'800'000.	2'400'000.	1'940'000.	3'350'000.	2'200'000.	2'300'000.
Carbon monoxide (CO)	g	1'200.	960.	2'700.	8'600.	18'000.	18'000.
Ammonia (NH_3)	g	0.53	0.39	1.5	3.2	0.82	0.94
Hydrofluoric acid (HF)	g	3.3	2.5	8.8	19.	5.1	5.8
Nitrous oxide (N_2O)	g	5.7	4.3	6.8	14.	5.3	5.9
Hydrochloric acid (HCl)	g	35.	25.	230.	430.	100.	110.
Sulphur oxides (SO_x) as SO_2	g	12'000.	11'000.	13'000.	49'000.	22'000.	25'000.
Nitrogen oxides (NO_x) as NO_2	g	12'000.	12'000.	16'000.	33'000.	19'000.	20'000.
Lead (Pb)	g	0.075	0.055	0.12	0.26	0.081	0.091
Cadmium (Cd)	g	0.02	0.014	0.014	0.03	0.015	0.016
Manganese (Mn)	g	0.017	0.013	0.05	0.11	0.027	0.031
Nickel (Ni)	g	1.	0.75	0.85	1.8	0.81	0.9
Mercury (Hg)	g	0.024	0.022	0.034	0.061	0.028	0.03
Zinc (Zn)	g	0.52	0.37	0.27	0.55	0.34	0.37
Metals	g	10.	66.	3.	10.	10.	10.
Radioactive substances	kBq	440'000.	330'000.	1'500'000.	3'600'000.	140'000.	160'000.
Aldehydes (R-CHO)	g						
Other organic compounds	g				8'500.	9'300.	9'400.
Chlorine	g			2.	2.		
Chlorinated HC	g			720.	25.		
Hydrogen sulphide (H_2S)	g						
Hydrogen (H_2)	g	10.	8.				
Water pollutants							
Waste water quantity	m3						
BOD	g	45.	150.	80.	70.	1'000.	1'000.
COD	g	360.	710.	1'100.	3'000.	3'100.	3'300.
AOX as Cl^-	g	0.1	0.074	0.03	0.058	0.057	0.062
Suspended solids	g	340.	690.	2'400.	63'000.	550.	610.
Phenols	g	6.	5.	1.1	8.	2.	2.2
Toluene (C_7H_8)	g	3.2	2.3	1.	1.9	1.8	1.9
PAH policycl. arom. HC	g	0.34	0.25	0.1	0.2	0.19	0.21
Aromatic HC	g	23.	17.	7.3	14.	13.	14.
Chlorinated HC	g	0.029	0.022	10.	0.023	0.019	0.02
Fats/oils	g	70.	61.	50.	50.	20.	20.
DOC	g	37.	50.	1'000.	3'000.	13'000.	13'000.
TOC	g	120.	94.	480.	230.	390.	400.
Ammonium (NH_4^+)	g	8.	14.	17.	34.	32.	35.
Nitrate (NO_3^-)	g	2.	2.	10.	21.	12.	14.
Nitrogen org. bound	g	9.6	6.9	2.4	4.6	5.2	5.6
Nitrogen total	g	8.	4.	3.	3.	30.	1.
Arsenic (As)	g	0.18	0.13	1.3	2.4	0.33	0.29
Chloride (Cl^-)	g	4'700.	3'500.	40'000.	454'000.	710.	710.
Cyanide (CN^-)	g	0.11	0.076	0.04	0.079	0.062	0.067
Phosphate (PO_4^{3-})	g	4.9	3.6	38.	71.	9.6	6.7
Sulphate (SO_4^{2-})	g	160.	120.	4'300.	18'000.	1'800.	1'800.
Sulphide (S^{2-})	g	<1	<1	0.25	0.49	0.47	0.5
Inorg. salts and acids	g	200.	150.	610.	1'220.	2'260.	2'280.
Aluminium (Al)	g	79.	58.	640.	1'200.	160.	140.
Barium (Ba)	g	72.	52.	70.	130.	50.	51.
Lead (Pb)	g	0.51	0.37	3.4	6.5	0.94	0.86
Cadmium (Cd)	g	0.033	0.024	0.042	0.079	0.025	0.025
Chromium (Cr)	g	1.	0.77	6.5	12.	1.7	1.6
Iron (Fe)	g	110.	82.	420.	840.	180.	190.
Copper (Cu)	g	0.44	0.32	3.2	5.9	0.82	0.72
Nickel (Ni)	g	0.47	0.34	3.2	6.	0.84	0.74
Mercury (Hg)	g	0.0015	0.0014	0.0017	0.0029	0.0016	0.0016
Zinc (Zn)	g	1.	0.75	6.5	12.	1.7	1.5
Metals	g	430.	330.	200.	140.	110.	120.
Radioactive substances	kBq	4'100.	3'000.	14'000.	33'000.	1'300.	1'500.
Other organic compounds	g						
Calcium ions (Ca^{2+})	g				200'000.		
Sodium ions (Na^+)	g	600.	610.	2'300.	3'200.		

Italic: data for provision from Boustead or ESU (cf. chapter 11.1)

* Distribution between fuel and feedstock: correction of APME (cf. chapter 11.1);
Emissions of biogenic CO_2 are not indicated (cf. chap. 8.1.1)

Table 11.28: Overview of the life cycle inventories for plastics: conclusion

The Process Assessment Matrix

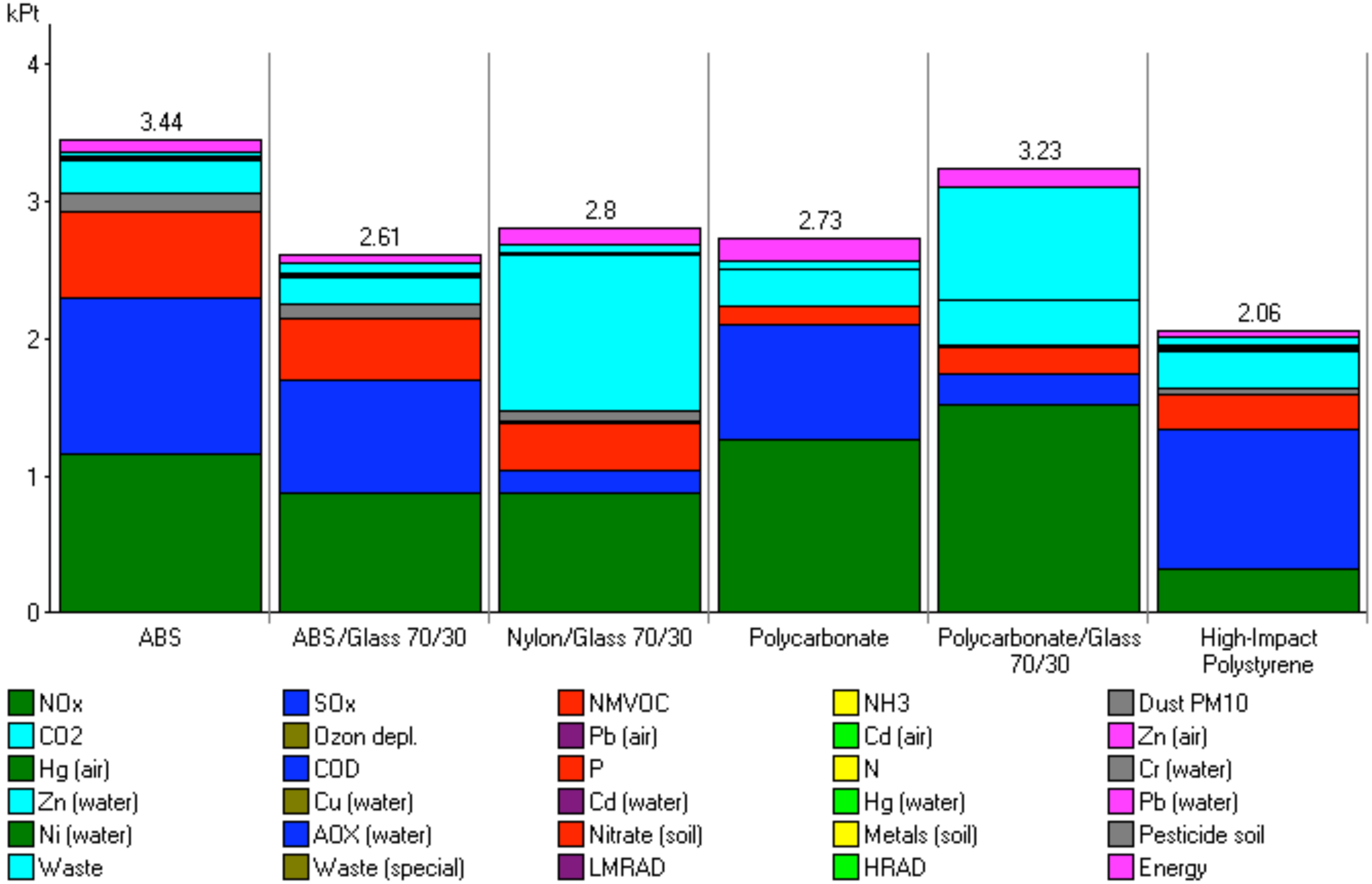
Process Analysis (Life Stages)	Non Hazardous Material Choices 1	Hazardous Materials Choices 2	Energy 3	Solid Residues 4	Liquid Residues 5	Gaseous Residues 6
	Inputs			Outputs		
Process infrastructure (facilities, equipment, maintenance)1	1.1	1.2	1.3	1.4	1.5	1.6
Manufacturing steps prior to process under analysis (PUA) 2	2.1	2.2	2.3	2.4	2.5	2.6
Process Under Analysis (PUA) Operation 3	3.1	3.2	3.3	3.4	3.5	3.6
Manufacturing steps following PUA 4	4.1	4.2	4.3	4.4	4.5	4.6
Process termination (Decommissioning) 5	5.1	5.2	5.3	5.4	5.5	5.6
Life-cycle of products that pass through PUA 6	6.1	6.2	6.3	6.4	6.5	6.6

BORIC SULFURIC

The Process Assessment Matrix

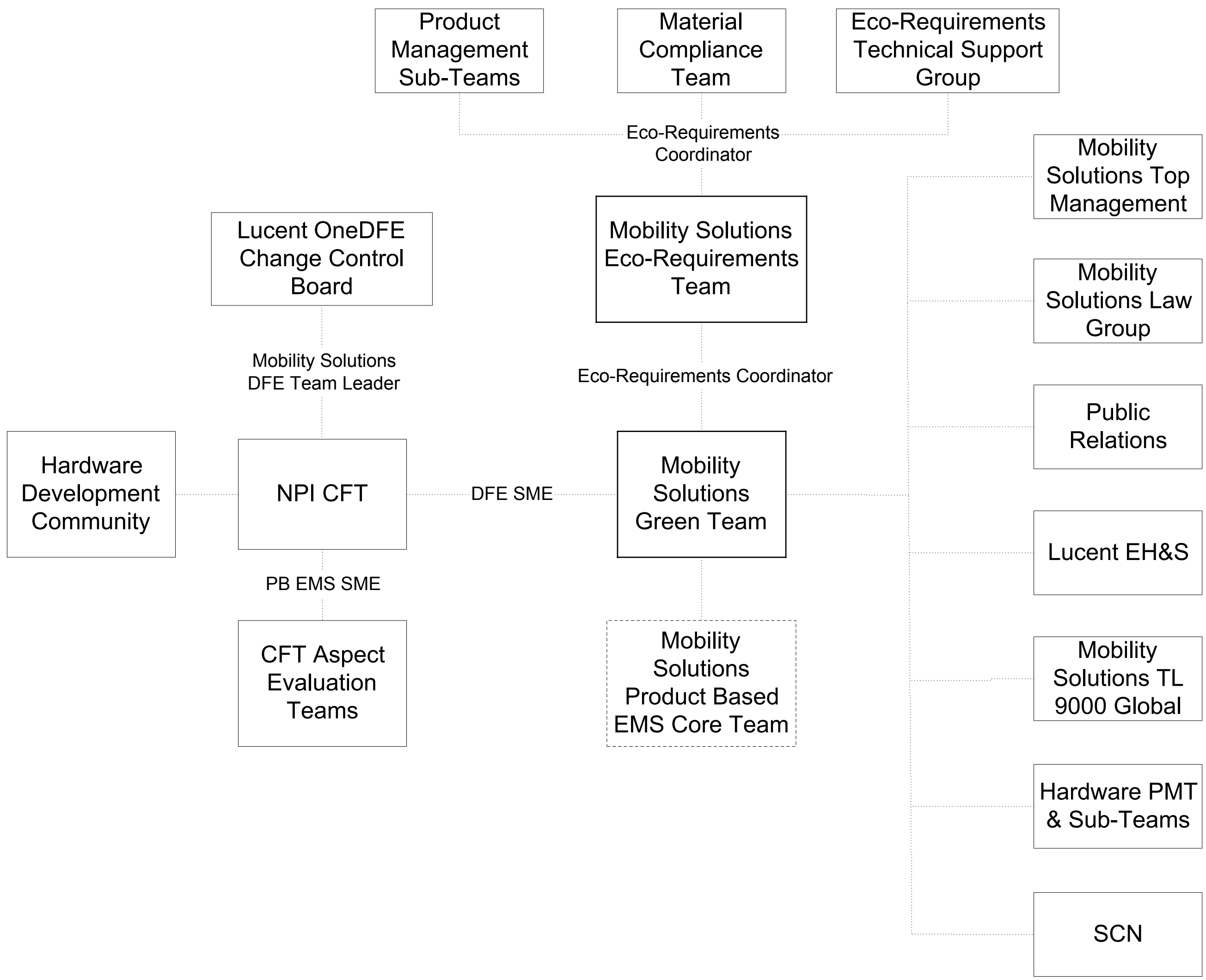
Process Analysis (Life Stages)	Non Hazardous Material Choices 1	Hazardous Materials Choices 2	Energy 3	Solid Residues 4	Liquid Residues 5	Gaseous Residues 6
	Inputs			Outputs		
Process infrastructure (facilities, equipment, maintenance) 1	1.1 3.3	1.2 1.7	1.3 3.1	1.4 0	1.5 1.4	1.6 2.3
Manufacturing steps prior to process under analysis (PUA) 2	2.1 1.3	2.2 2.5	2.3 1.7	2.4 1.3	2.5 2.9	2.6 0.0
Process Under Analysis (PUA) Operation 3	3.1 0	3.2 1.1	3.3 .9	3.4 1	3.5 1.7	3.6 .4
Manufacturing steps following PUA 4	4.1 1.3	4.2 3.8	4.3 3.1	4.4 1.4	4.5 2.9	4.6 2.2
Process termination (Decommissioning) 5	5.1 1.0	5.2 0.8	5.3 2.5	5.4 0	5.5 1.7	5.6 0
Life-cycle of products that pass through PUA 6	6.1 0	6.2 1.1	6.3 3	6.4 0	6.5 2	6.6 0

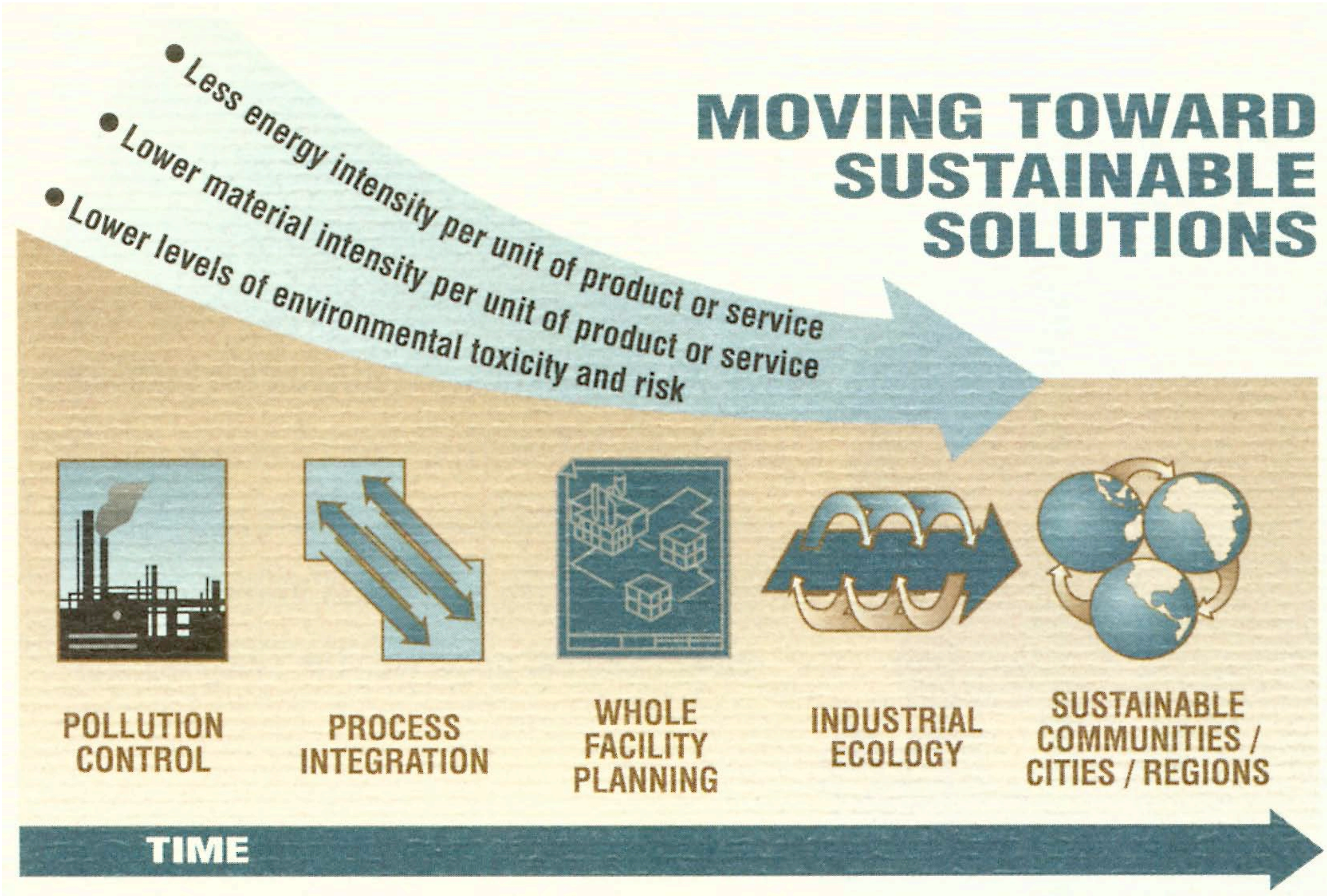
Lifecycle Impact: Structural Plastics



Compare report setup 'Structural Plastics'; Method: Ecopoints 1997 (CH) / Ecopoints / indicator

Lucent Business Integration Structure




MOVING TOWARD SUSTAINABLE SOLUTIONS
• Less energy intensity per unit of product or service
• Lower material intensity per unit of product or service
• Lower levels of environmental toxicity and risk
POLLUTION CONTROL
PROCESS INTEGRATION
WHOLE FACILITY PLANNING
INDUSTRIAL ECOLOGY
SUSTAINABLE COMMUNITIES / CITIES / REGIONS
TIME

DFE & Sustainable Development

DFE seeks to:

- Reduce Environmental Impact
- Increase Resource Productivity
- Increase Eco-efficiency (i.e., drive toward sustainability)

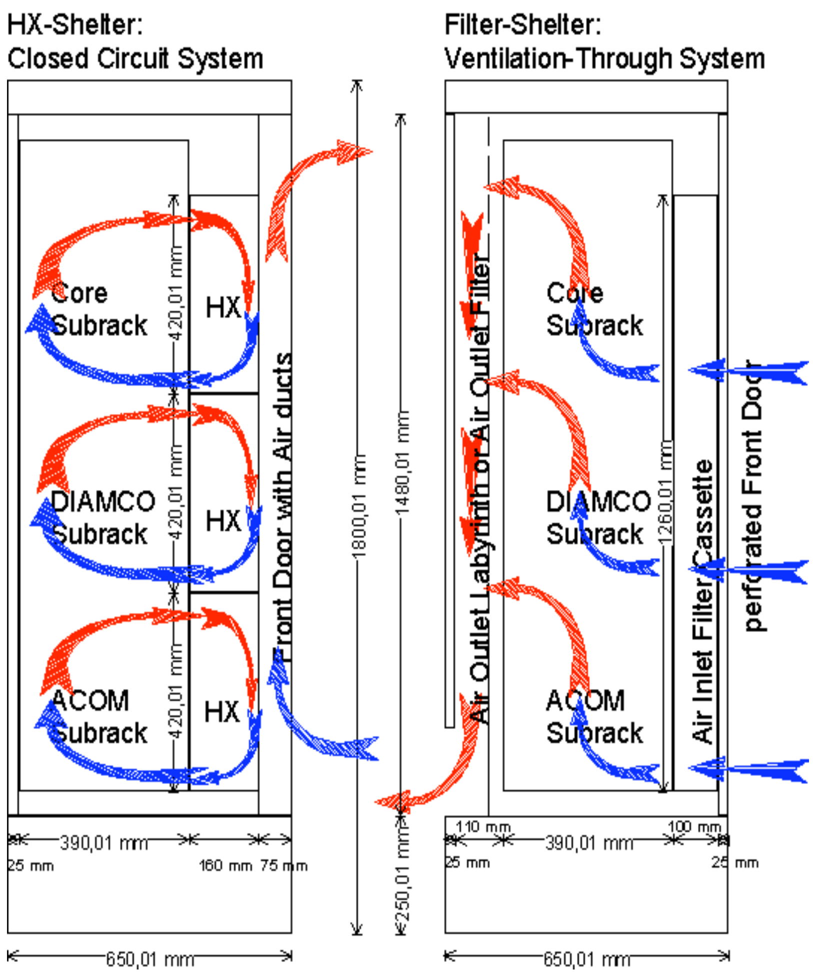
”The two technologies with the biggest potential to make a significant contribution to sustainable development are expected to be energy generation from renewable sources and telecommunications”
EURESCOM/ETNO

Siemens Base station BS 240 / 241

Winner in Category environmentally compatible products of

- Siemens Environmental Award 2000 -

Advanced Cooling by Membrane filter (Outdoo
(EU- Patent)



Saving Heatexchanger

- 7 K better heat balance
- MTBF - improvement 31%
- Cost reduction 33%
- Weight reduction 50%
- Volume minus 38%
- Energy consumption minus 180 W

Critical Elements

- Life cycle thinking/systems perspective
- Balancing multiple impacts aspects and criteria
- Rooted in design development, engineering, and quality
- Integrated in the product design process
- Proactive and team approach

Typical Opportunities

- Reduced material intensity
- Reduced energy intensity
- Reduced toxic substances amts/dispersion
- Enhanced recyclability
- Extended product life
- Increased service intensity
- biomimicry

Critical Elements

- Values are important
- Transparency is important
- Needs to be actionable
- Proper education and introduction

DfE is helping make the connection between business and the environment

- Tools are available to build links between the right actors--purchasing, accounting, design
- Provides a meaningful environmental dialogue in an appropriate language
- A way of making long term thinking actionable
- Expands (redefines?) business sense of “community”

DfE Observations/Lessons Learned

- Don't create an unsolvable problem for a designer. It creates frustration
- We never seem to have the right data/information
- Decision makers seem more interested in information than tools
- Connection to business strategy is critical.
- Customers can drive this activity through quality programs

DfE Observations/Lessons Learned

- DfE capability exists in many multi-national companies but may not be used consistently
- Need more capacity to do these evaluations
- Mental maps need to be changed in the long run and DfE helps.
- There are very powerful reasons to connect to quality programs and “lean thinking.”
- Education focusing on different levels of management is needed

DfE Observations/Lessons Learned

- Move from cutting costs to exploiting innovation
- The supply chains are growing very close to the OEM due to e-commerce, bringing environmental risk.
- It is challenging to mix various value systems, equity, society, global and inter-generational issues.
- The notion of a potentially abrupt environmental disaster is hard to communicate to business people